NRL Report 5961

SEA WATER BATTERY PLUS TUNNEL DIODE CONVERTER AS A POWER SOURCE

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ABSTRACT

To fill the need for a low-power, reliable, long-duration, maintenance-free power source for remote marine applications, the combination of a single cell sea water battery with a tunnel diode converter to step up the voltage is proposed. The devices should be designed for integration as a single unit for a given load and lifetime. The sacrificial anodes used in the battery can be replaced after they have been expended, but the static converter can be re-used indefinitely. The compatibility of the magnesium-iron sea water battery and tunnel diode converter has been demonstrated as a practical power source. It would have applications for powering remote buoys or oceanographic instrumentation. As a power source for radio distress transmitters for small boats or ditched aircraft, it would be particularly attractive because of an indefinite shelf life.

AUTHORIZATION

NRL Problem 52E02-02
Projects RR010-01-44-5601,
SF013-06-29, Task 2857, and
SR007-12-01-0800

PROBLEM STATUS

This is the final report on this particular phase of the problem; work is continuing on other phases of the overall problem.

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INTRODUCTION

A low-power, reliable, long duration, maintenance-free power source would fill a need for isolated marine applications such as buoys providing audible, visual, or radio-frequency signals or anti-submarine monitoring beacons. It could also be used for remote oceanographic instrumentation systems or for radio distress transmitters for small boats or ditched aircraft. The tunnel diode converter/sea water battery electric source described in this report has been demonstrated to be feasible for such applications.

The tunnel diode static converter shown in Fig. 1 has been developed at the U.S. Naval Research Laboratory for the conversion of low d-c voltages (.25 volt) to higher, more useful levels and the explanation of its operation is given in references 1 through 3. Experience has demonstrated the stability and reliability of this device provided the input voltage is between .2 and .3 volt (for germanium tunnel diodes) and the primary impedance (including the internal impedance of the generator) is sufficiently low. The output is a square wave whose frequency depends upon the number of turns on the primary, the size of the transformer core and the input voltage. The magnitude of the output voltage depends upon the turns ratio of the transformer and the input voltage. If a d-c output is desired, the square wave can be rectified with very little ripple produced.

This converter may be powered by a consumable-anode magnesium sea water battery which is simple and rugged. Capable of prolonged operation, it may provide energy at an anode material cost of about $25 per watt-year.

SEA WATER BATTERY WITH TUNNEL DIODE STATIC CONVERTER

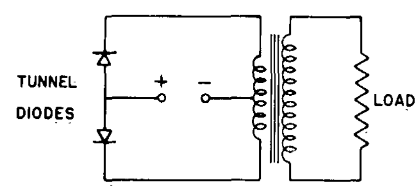

Fig. 1 - Tunnel diode static converter

The use of a suitable sea water battery in conjunction with the tunnel diode converter is an attractive solution to this problem. A practical sea water battery has long been considered desirable for remote marine operation. However, past studies have striven to obtain the highest possible voltage per cell to minimize the number of cells required in series and the highest efficiency to minimize size and weight. However, when striving for these goals, usually the use of expensive materials are indicated. If, however, the requirements for a high voltage per cell is eliminated, cheaper, more common materials can be used in a single cell provided a converter steps up the low output voltage of a single cell to the desired level. When used in this manner, sacrificial anodes can be employed as expendable fuel to be replaced after a given lifetime, but the same converter can be used indefinitely.

To investigate the compatibility of a sea water battery and the tunnel diode converter, a battery was constructed with a designed output of 10 amperes at .25 volt. This battery was constructed in accordance with the principles explained in U.S. Patents 3,036,141 and 3,036,142 issued to Leo Goldenberg and Morris Fidelman and dated May 22, 1962 (4, 5).

It consisted of 12 magnesium plates (connected in parallel) and 13 steel plates with a flash nickel plating (connected in parallel). The effective dimensions of each plate was 5-13/16" x 9" giving a total effective area of 8.7 sq. ft. The plates were separated by approximately 3/32". The magnesium plates were employed sacrificially and constituted the negative terminal of the battery. The steel plates were not altered by the electrochemical reactions in the cell and constituted the positive terminal of the battery. The electrolyte used was a solution of Sea-Rite (35 gms/liter of water). This is a commercially available combination of chemical compounds mixed in the proper proportion to simulate sea water. The chemical composition supplied by the manufacturer (Lake Products Company, St. Louis, Mo.) is given in Table 1.

Table 1
Composition of Sea-Rite

Sodium	30.577%
Magnesium	3.725%
Calcium	1.178%
Potassium	1.099%
Strontium	.0382%
Boron	.0135%
Chloride	55.035%
Sulphate	7.692%
Bromide	.1868%
Bicarbonate	.405%
Fluoride	.0039%

Electrolyte consisted of 35 gms. of Sea-Rite dissolved in each liter of water.

The load regulation curve was obtained for this battery and is shown in Fig. 2. Note the shape of this curve, which is relatively flat for terminal voltages between .2 and .3 volt. This characteristic is ideal for the tunnel diode converter and indicates their compatibility. As a demonstration of such a system, the gas-tube light flasher circuit shown in Fig. 3 was designed using the sea-water battery described above, in conjunction with a tunnel diode static converter using germanium tunnel diodes with peak currents of 10 amperes. The transformer core used was type 50030-2A (Magnetics, Inc.) with 4 turns on each half of the primary and 8600 turns on the secondary. This provided an output of approximately 450 volts. When the cold cathode discharge tube, type 5823, breaks down allowing its associated capacitor to discharge through the pulse transformer, a high voltage pulse is applied to the electronic flash tube FT-106 causing it to break down until its capacitor is discharged. The cycle is then repeated. This produced a periodic flashing light similar to what might be used on a visual beacon. This circuit was not designed for a particular application, but merely to demonstrate the principles and compatibility of the system. It showed that the internal impedance of such a sea water battery was sufficiently low to operate a tunnel diode converter and also the feasibility of stepping up such low voltages to any reasonable output desired (from .25 volt on the input to 450 volts on the output in one step). It also indicated the design requirements for both the sea water battery and the tunnel diode converter.

DESIGN CONSIDERATIONS

The battery regulation characteristic (Fig. 2) should be as nearly flat as possible between the limits of .2 and .3 volt for a wide range of current, unless special techniques are employed to start the converter and to allow for changes in load. To insure operation at a given point on the curve for a given load, the battery must be designed with the proper cross-sectional area to obtain the required current density. It is possible that the battery characteristic can be improved for this application by the use of other materials. For example, it has been suggested that a very light flash plating of palladium on top of the nickel-plated steel plates might improve the battery characteristics, but this

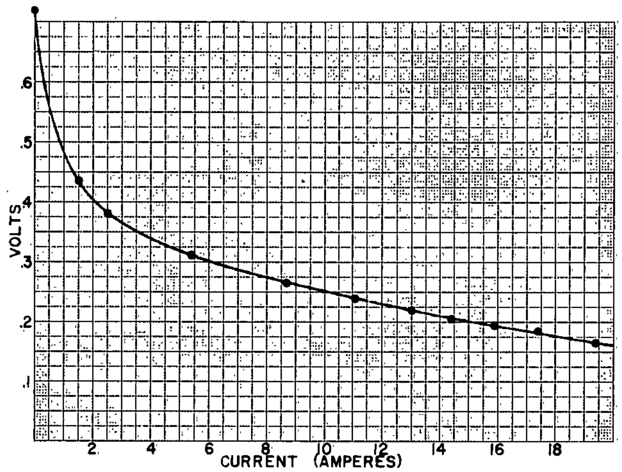

Fig. 2 - Battery regulation curve

has not been demonstrated in conjunction with this system. The design lifetime of the battery will depend upon the quantity of material included in the sacrificial plates. This is the primary factor governing the size and weight of the installation.

The inverter design will depend, of course, on the output voltage and power required. The power output obtainable from such a system is limited at the present time by the efficiency and peak current limitations of the tunnel diodes available. Consequently such power sources are limited to somewhat less than 100 watts in the foreseeable future.

RESULTS AND CONCLUSIONS

The sea water battery with a tunnel diode static converter has been demonstrated as a practical power source for long duration, low power applications in isolated marine locations. It might be useful in buoys providing visual, audible, or radio frequency signals, antisubmarine monitoring beacons, or remote oceanographic instrumentation. It could also be used as an emergency power source for radio distress transmitters for small boats or ditched aircraft, especially since it would have an indefinite shelf life.

The tunnel diode converter sea water battery system should be designed as an integrated unit for a given load and life. When the sacrificial plates of the battery are expended, they may be replaced with the converter being re-used indefinitely.

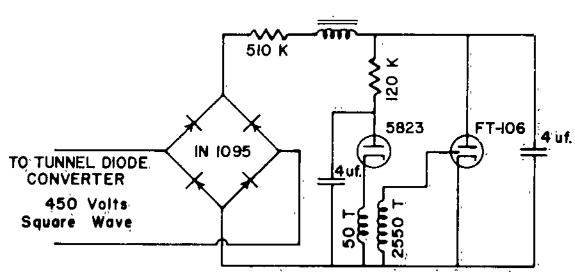

Fig. 3 - Flashing light circuit

ACKNOWLEDGMENT

The assistance of Leo Goldenberg in the design of the sea water battery used in this investigation is gratefully acknowledged.

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5. U.S. Patent No. 3,036,142, Primary Battery dated May 22, 1962, Leo Goldenberg and Morris Fidelman.

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